

SYSTEM AND METHOD FOR EMERGENCY CALL CHANNEL  
ALLOCATION

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## SYSTEM AND METHOD FOR EMERGENCY CALL CHANNEL ALLOCATION

### FIELD OF THE INVENTION:

The present invention relates to a wireless communication system. More particularly, the present invention relates to an emergency call system which improves the grade of service (GOS) of a wireless communication system that has reached its maximum call capacity.

### BACKGROUND:

Wireless local loop systems are used in remote locations which typically have electricity but do not have telephone service. Instead of spending money on providing a wireline telephone service, it is typically easier to use a wireless local loop system. The wireless local loop system allows a user to operate a telephone at a remote site. The typical wireless local loop system includes at least one telephone device which is connected to an interface which in turn is connected to a radio telephone transceiver (either cellular or other wireless systems). The combination of the telephone device or devices and the remote radio telephone transceiver is referred to as the "subscriber unit."

In a wireless local loop system, the link from the subscriber unit to the telephone system, for example, the local-exchange switch, is provided at least partially by a wireless communication channel. For example in a cellular wireless local loop (WLL) system, each subscriber unit is in a fixed location and communicates with a cellular radio base station responsible for all subscriber units within a cell. Sets of subscriber units communicate with one or more base stations which in turn are connected to the rest of the telephone network, typically a local exchange switch or other voice switching communications network router.

A caller cannot place a call in a wireless local loop system without a communication link existing between the subscriber unit and telephone system, including a wireless communication channel between the subscriber unit and the base station. In a typical wireless local loop system, there are usually more subscriber units than available wireless communication channels for audio links. Therefore in an emergency situation, a

caller might not be able to make an emergency call because there are no wireless communication channels available.

*a* In wireless telephone systems, the failure <sup>to obtain</sup> ~~of obtaining~~ an open communication channel to place a telephone call is an "accepted evil." However if someone is trying to place an emergency call, this accepted evil can be fatal. In an emergency, it is imperative that a caller be able to dial an emergency telephone number. An emergency telephone number can be "911" or the telephone number for the police, ambulance, fire department, poison control, or another known emergency telephone number.

A wireless local loop system subscriber unit may have a locally generated dial tone to simulate the "look and feel" of a conventional wireline telephone device when the handset is taken "off hook." Alternatively, detecting an off hook condition on the telephone device of the subscriber unit may lead to a channel assignment request being made to a base station. Once a wireless channel is assigned, this being a channel for an audio link, a dial tone is generated by the switch and transmitted to the subscriber unit as in conventional wireline systems. The embodiments of the present invention are more suitable to this second case but may be used in both cases. The embodiments of the present invention also are suitable for use in a regular cellular system wherein the subscriber units are not necessarily fixed in location and may not necessarily be attached to a "plain old telephone set" (POTS).

In a wireless local loop system in which a dial tone is not generated until an audio-grade communication channel is assigned from the subscriber unit to the local switch, three things must occur in order to allow a caller to dial an emergency number without the presence of a dial tone: 1) the caller must be able to dial a telephone number, even without requiring a switch-generated dial tone or indeed any dial tone to be present, 2) the telephone number dialed must be recognized in some manner as an emergency call, and 3) the call must be placed if indeed it is recognized as an emergency call. Present day wireless telephone systems, whether wired or not, do not allow a call to be placed in this manner.

Therefore there is a need for a telephone system which activates an emergency call recognition system, recognizes when an emergency number is dialed and provides a

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communication channel for the caller to complete such a call even at maximum capacity. Such a system also would cut off or otherwise compromise the service quality of those calls that are not emergency calls when the system is operating at such maximum capacity.

## 5 SUMMARY

One feature of the present invention is allowing for the placement (by dialing) of emergency telephone calls in a wireless system operating at capacity.

Another feature of the present invention is providing a communication channel to a caller who is placing such an emergency call in a wireless system.

10 Another feature of the present invention is using an emergency call recognition system which compares the dialed number (a sequence of digits) to one or more predefined digit sequences defined as emergency telephone numbers in a wireless system.

15 Yet another feature of the present invention is recognizing if an emergency telephone number has been dialed without requiring a dial tone in a wireless system.

Yet another feature of the present invention is providing an indicator to a caller if all of the communication channels are in use in a wireless system.

20 One aspect of the present invention is an emergency call recognition system which is part of a wireless system and which recognizes when a dialed number is an emergency number is dialed and which provides a wireless communication channel to the caller to complete the call when the call is determined to be an emergency call. Thus, the present invention allows emergency calls to be made at any time by ensuring allocation of a communication channel for this purpose.

25 In a first embodiment of the present invention, a certain number of wireless channels of the totality of communication channels licensed to a wireless system are reserved for the purpose of determining at the base station if a set of dialed digits is an emergency call when all the non-reserved channels are busy. While this reduces to some extent the maximum capacity of the system for non-emergency calls, the grade of service (GOS) for emergency calls is dramatically improved.

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In a second embodiment of the channel allocation of the present invention, a number of low-bit-rate wireless communication channels is reserved for the purpose of recognizing at the base station when an emergency call is being made when all full-rate channels are busy. These low-bit-rate channels typically are not sufficient for an audio communication, for example, for voice or a facsimile. The recognition preferably is digit by digit. After emergency number determination, via a priority recognition system, the emergency call is given a full-rate (*e.g.*, audio-grade) wireless communication channel by cutting off an existing full rate non-emergency telephone call or downgrading the bit rate of one or more non-emergency telephone calls.

In a third embodiment of the channel allocation of the present invention, the subscriber unit recognizes an emergency telephone number, preferably digit by digit. Thereafter the subscriber unit sends an emergency link request to the base station. If there are no available channels, the base station assigns a channel by disconnecting or otherwise downgrading an existing telephone call that is not an emergency call or degrading the bit rate of existing non-emergency calls, providing the freed channel to the emergency caller.

As defined herein, an emergency call is defined as a sequence of digits of a set of pre-defined emergency digit sequences (*e.g.*, 911). Any user who dials a pre-configured emergency number using either DTMF or pulse dialing will have an improved chance of seizing a channel on a congested system. Emergency numbers can then be detected in the base station of the wireless local loop or, in another embodiment, in the subscriber unit of the present invention, for example, before channel allocation. In the preferred embodiment, emergency numbers are detected on a digit by digit basis to rapidly determine if the sequence is not an emergency number, such determining being possible before all the numbers have been dialed, thereby speeding up the determination of which telephone calls are not emergency numbers.

## BRIEF DESCRIPTION OF THE FIGURES

**Fig. 1A** illustrates an overview of a subscriber unit on which a preferred embodiment of the present invention is implemented;

**Fig. 1B** illustrates an overview of a communication station (*i.e.*, a base station) on which an alternate embodiment of the present invention is implemented;

**Fig. 2** illustrates a procedure for using one embodiment of the present invention;

**Fig. 3A** illustrates a data flow diagram of the decision process for allowing  
5 emergency calls to be placed;

**Fig. 3B** continues the illustration of flow diagram for the decision process of allowing an emergency call using the present invention; and

**Figs. 4A and 4B** illustrate another embodiment of the present invention which uses a low rate uplink to the base station where detection of the emergency number  
10 sequence is made.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

One aspect of the present invention is a system and method for emergency call channel allocation in a wireless system. The technology of the present invention allows emergency calls to be placed by a user in distress (or is otherwise a priority user) even  
15 when the wireless system is operating at capacity, that is, all wireless communication channels are in use. The various embodiments of the present invention are described in detail below. They share certain common characteristics however such as:

1. Sequence recognition of emergency numbers, preferably digit-by-digit and
2. Methodology that insures that a wireless communication channel is assigned  
20 to a caller once an emergency number sequence is recognized.

*a* In all <sup>embodiments</sup> ~~embodiment~~, a wireless local loop system having a limited number of communication channels is addressed. In a wireless local loop system, the subscriber unit establishes two way communications with a base station which in turn is linked to a master cellular-type switching center which is in turn is linked with a local telephone  
25 central switching office (the switch). A base station transceiver establishes a link with a subscriber unit transceiver by assigning a wireless communication channel between the base station and the subscriber unit. Note that the terms base station and communication station are used interchangeably herein.

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In the preferred embodiment, the base station transceiver uses an array of antenna elements together with spatial processing to communicate with the subscriber unit. Such spatial processing clearly is not a necessary part of the invention. During reception, the spatial processing acts on the signals received at the antenna array and in particular transforms the antenna signals into a received signal from a particular subscriber unit. During transmission, the spatial processing transforms a to-be-transmitted signal into antenna signals to be transmitted at the antenna array elements to the subscriber unit. The spatial processing, preferably linear spatial processing is adaptively determined. Such systems are sometimes called "smart antenna" wireless communication systems. Such spatial processing of the antenna signals potentially provides several signal quality advantages, including increased cell-phone capacity in each cell. In some cases, smart antenna systems enable simultaneous communications over the same "conventional communication channel." This is sometimes called spatial division multiple access (SDMA). A conventional communication channel is a frequency, time, or code communication channel or a combination of these. For a description of spatial processing See U.S. Patent 5,592,490 to Barratt *et al.*, incorporated herein by reference. While smart antenna systems with spatial processing allow for SDMA, that is, more than one "spatial communication channel" per conventional communication channel, many of the advantages of spatial processing are still available even with one spatial communication channel per conventional communication channel.

The present invention, however, is not restricted to using smart antenna wireless communications systems.

Referring to **Fig. 1A**, an overview of one embodiment of the present invention is illustrated. While the system is shown operating in a wireless local loop system, other wireless systems in which part of the link from a subscriber unit to the telephone network is via a wireless link between the subscriber unit and a base station. In a wireless local loop system, a telephone device **100** is a connected part of a subscriber unit **102**. The subscriber unit **102** interfaces the telephone device **100** with the rest of the WLL system. The subscriber unit also comprises a transceiver **104**. The telephone device **100** may be a conventional telephone POTS (for Plain Old Telephone Set), facsimile machine, data modem, or cordless telephone now common in many homes. Typically, the subscriber

unit transceiver **104** is mounted at a fixed site on the outside of a structure such as an office or home. The subscriber unit transceiver **104** is used to transmit and receive telephone calls to and from a base station and other telephone devices via antenna **106**.

The interface preferably comprises a power supply (not shown), a circuit for  
 5 detecting whether the telephone device is in an on-hook or off hook state **101**, a  
 telephone number converter **103**, and a digital signal processor (DSP) **108** having storage  
 for programs **110**. These include programs <sup>to</sup> provide a priority communication channel  
 request, and, in some embodiments, for performing emergency call recognition based  
 upon emergency call number sequences stored in a memory **112** of the DSP **108**. In the  
 10 preferred implementation, the DSP **108** and memory **112** are both part of the subscriber  
 unit transceiver **104**, and also perform other functions such as signal modulation and  
 demodulation. All non-DSP implemented parts of the transceiver, such as the receiving  
 and transmitting RF components, the digital to analog and analog to digital converters,  
 etc., are shown in block **105**. The interface power supply is the same as the power supply  
 15 that supplies power to the rest of the subscriber unit, for example the subscriber unit  
 transceiver.

Note that because it is anticipated that DSP functionality, including DSP  
 programs, may in the future be incorporated into special purpose hardware, for example  
 as part of an application specific integrated circuit (ASIC) or part of a very large scale  
 20 integrated circuit (VLSI), and because DSP functionality may also be met by other  
 processors, for example a general purpose microprocessor, the term digital signal  
 processor as used herein includes these equivalent alternatives.

In those embodiments wherein the emergency call recognition program is in the  
 subscriber unit DSP, the telephone number converter **103** converts individual standard  
 25 DTMF (touch-tone) or pulse dialing signals from the telephone device into digital  
 signals. The subscriber unit DSP-based recognition program has at least one predefined  
 sequence of digits, representing an emergency number which a user dials using telephone  
 device **100**. The sequences are shown as Emer. #1,..., Emer. #12 stored in memory **112**  
 of DSP **108**.

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The emergency call recognition program is a series of instructions for performing digit-by-digit comparison of dialed digits to stored digits representing an emergency number and is programmed to recognize at least one emergency telephone number. The emergency telephone numbers can include the telephone numbers for the police, ambulance, fire department, poison control, 911, or any other emergency telephone number, however this list is not meant as a limitation. It is anticipated as within the scope of the present invention to have emergency numbers to be programmable by a technician in the factory or in the field.

As each digital signal is generated it is compared to a digit of an emergency number. The emergency call recognition program of the DSP recognizes if the dialed telephone number is an emergency telephone number by using digit comparison. Emergency number recognition program compares the converted digital signals to at least one predefined sequence for an emergency telephone number in digital form. The at least one predefined sequence of emergency telephone number in digital form is stored in the memory **112** of the DSP **108**.

The emergency call recognition system is initiated as soon as an off-hook state is determined at the subscriber unit. The emergency call recognition system does not require the presence of a dial tone. Some implementations may include locally generating (*i.e.*, "faking") a dial tone, while others may include, upon an off hook condition being obtained, opening a non-audio wireless channel to convey dial-tone status from the switch. Alternatively, upon off-hook, after the subscriber unit fails to obtain a channel, a special "dialing in progress" tone (which might simply be silence) is provided to the telephone device during the dialing.

Digit by digit dialing analysis comprises a method for discriminating between a potential emergency sequence and a non-emergency sequence. For example, if 9-1-1 was the only valid emergency number, means would be included for distinguishing digit-by-digit between the following three, possibly partial, digit sequence cases:

1. the given, possibly partial, digit sequence could be the beginning of an emergency call, or not, but we cannot determine yet. For example 9-1-... could be the beginning of 9-1-1 which would be an emergency call or it could be the beginning

of 9-1-2-6-2-1-7 which might be a legitimate non-emergency call. The point is that up to the point of 9-1-..., the complete decision cannot yet be made and we must continue to wait for the subscriber to dial more digits.

2. no matter what digits follow the given, possibly partial, digit sequence, it could not become an emergency call phone number. For example 9-1-2-... cannot become an emergency call by the subsequent dialing of additional digits. The complete decision can be made and call resources can be freed immediately.
3. the digit sequence dialed so far represents a complete emergency phone number and the call should be connected expeditiously. In this example, only 9-1-1 is a complete emergency number.

In the preferred embodiment, this digit-by-digit number analysis allows non-emergency call determination as early as possible during congested situations where non-emergency calls are being dialed. While this early detection of non-emergency call numbers feature may optimally allocate call resources, the present invention, however, is not restricted to such careful implementations.

In yet another alternate embodiment, the emergency call recognition program recognizes the dialed telephone number by using audio (DTMF) comparison. Methods for recognizing, *i.e.*, discriminating between a set of audio patterns are well known in the art. For example, methods using hidden Markov models are widely used in speech recognition and may easily be adapted for this application. The emergency call recognition program compares the DTMF audio signals to at least one predefined audio sequence for an emergency telephone number. Predefined audio sequences may also be stored in the memory of the DSP. The at least one predefined audio sequence for an emergency telephone number in digital form is located in ~~is located in~~ memory **112** of DSP **108**.

Storing the different sequences of emergency numbers in the memory of the DSP can be accomplished in a variety of ways. In one embodiment, a technician stores the emergency telephone numbers in the DSP memory **112**. This can be done at the store or during the installation of the telephone system. In another embodiment, the users are able to store their own emergency telephone numbers in the DSP memory **112**. In another

embodiment, the manufacturer stores the emergency telephone numbers for a specific geographic area in the DSP memory **112**.

In yet another embodiment, the emergency telephone numbers are entered automatically once the subscriber unit **102** is initialized with the rest of the system for the first time. In this embodiment, once the subscriber unit **102** is initialized, the subscriber unit makes a wireless connection to a base station which downloads the emergency numbers for the given area. In addition, the subscriber unit **102** can periodically make wireless connections to the base station to update the emergency numbers for a given area.

Several formats for storing the numbers are possible within the scope of the invention. One form is a table enumerating all possible emergency call phone numbers. Alternatively, compressed forms such as regular expressions may be used. A regular expressions is an expression in a syntax for specifying strings, typically for matching operations. See J. E. F. Friedl, *Mastering Regular Expressions: Powerful Techniques for Perl and Other Tools*, Sebastopol, California: O'Reilly & Associates, 1997. (ISBN: 1565922573). Alternatively, the numbers may be stored as a set of rules, for example matching rules suitable for rule-based-analyses. Other well known storage schemes suitable for matching also may be used. For example, if 7 digit numbers beginning with 123 are emergency numbers, then this could be stored as a table enumerating 10,000 possibilities or, more compactly, as the rule "1-2-3 followed by any four digits" or as a regular expression like "123????". Of course combinations of these techniques are also anticipated such as lists of regular expressions. Each of the storage methods would be accompanied by a corresponding method for discriminating between an emergency and a non-emergency sequence. If the DSP recognizes an emergency number, the DSP sends an emergency (*i.e.*, priority) communication channel request to its base station in the WLL system. The request for a priority communication channel assignment is transmitted by subscriber unit transceiver **104** to the base station. The base station responds to the request for a priority communication channel assignment by providing a communication channel to the emergency caller. The base station disconnects a non-emergency call to provide the emergency caller a communication channel in the case that no other communication channels are available.

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Referring to **Fig. 1B**, an overview of another embodiment of the present invention is illustrated. **Fig. 1B** shows a communication station (*i.e.*, a base station) **122** which is part of a wireless local loop system and is connected to a telephone network **120**. The base station **122** interfaces the telephone network **120** with the rest of the WLL system, including its subscriber unit **102**. The base station also comprises a transceiver **124**, which in the preferred embodiment uses an array of antennas **126** to communicate with its subscriber units, such as subscriber unit **102**. In one embodiment, the base station comprises at least one digital signal processor (DSP) **128** having storage for programs **130**. These include programs to provide a priority (emergency) communication channel between the telephone network and a subscriber unit, and, in some embodiments, for performing emergency call recognition based upon emergency call number sequences stored in a memory **132** of the DSP **128**. The preferred embodiment uses the DSP(s) of base station transceiver **124**. Note that while the preferred embodiments described herein include DSP programs, as in the subscriber unit of **Fig. 1A**, such DSPs and programs may in the future be incorporated into special purpose hardware, for example as part of an application specific integrated circuit (ASIC) or part of a very large scale integrated circuit (VLSI). As would be clear to those of ordinary skill in the art, a general purpose microprocessor may also be used instead of a DSP device. Also, the DSP function may be incorporated into part of a larger ASIC as is common in the art.

The storage of the emergency calls and the emergency call recognition program is as described above for the case where the call recognition program is in the subscriber unit DSP **108**. In this case, the at least one predefined sequence of digits, representing an emergency number, are shown as Emer. #1,..., Emer. #12 stored in memory **132** of DSP **128**.

### *Subscriber Unit Detection of Emergency Numbers*

Referring to **Fig. 2**, the procedure for one embodiment of the present invention where channel allocation is made from existing utilized channel and where emergency call sequence recognition occurs in the subscriber unit is illustrated. The telephone device goes off-hook **200**. The subscriber unit requests a communication channel **202** from the base station. At this point, a dial tone is not present. The base station determines

if there is an open communication channel which can be assigned to the telephone device **204**. If there is a communication channel available, the communication channel is assigned to the caller **206**. The switch then provides a dial tone to the caller **208**. The caller now dials the number **209** and the call proceeds as a normal call **210**.

5        If there are no communication channels available, then the telephone device is provided with an indicator that a channel is not available, *i.e.*, a “try-later” signal such as a “fast busy” signal, and the subscriber unit begins to listen for DTMF tones **212** generated by the user dialing the emergency number. Once a DTMF tone is detected by the DSP, the “fast busy” signal is terminated **214**. The DTMF tones are then converted to  
10    digital signals in a sequence and sent to the DSP **216**. An emergency call recognition program then compares the digital signals, digit by digit, to at least one predefined emergency telephone number **218**. If any one digit of the sequence of digital signals fails to match the predefined stored emergency telephone number **220** when that digit is dialed, then the call is disconnected **221**.

15        If the sequence of digital signals dialed matches a predefined stored emergency telephone number **220**, then an emergency (*i.e.*, priority) communication channel request is sent to the base station **222**. The base station then disconnects an existing call **226**, and assigns this channel to the user. The Call Disconnect procedure is described below. The base station then assigns a channel to the user, thus opening a path to the telephone  
20    device from the switch and passing the switch-generated dial tone to the telephone device **228**. Upon detection of the dial tone by the DSP, the DSP dials the pre-configured emergency number stored in the memory of the DSP **230** that was recognized by the DSP and which the caller previously dialed. Once the DSP completes dialing the entered emergency number, the call proceeds as a normal call **210**.

## 25    **Subscriber Unit-Based Discrimination: Some Variations**

      The subscriber unit typically contains the following elements: a circuit for detecting whether or not the telephone set is “off-hook, *i.e.*, activated or deactivated, a circuit for converting the telephone set audio-band analog signals into digital signals, a signal processing mechanism capable of recognizing emergency telephone numbers by  
30    comparing digit sequences to a pre-stored emergency phone number description, the

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description being of one or more pre-defined emergency number sequences and stored using table enumeration, regular expression, procedural description, or rule-based description, a channel requesting mechanism, a mechanism capable of notifying the base-station that the requested call is of an emergency or priority nature, and a processing  
5 mechanism capable of continuing or discontinuing call progress based on digit sequence detected or upon request of a base-station.

In the embodiment in which the dialed digit detection and phone number analysis for the purpose of emergency/non-emergency call discrimination occurs in the subscriber unit, several variations are possible as to what happens once an off-hook state is detected  
10 at the subscriber unit. For example, upon off-hook, the subscriber unit can immediately fake a dial tone. At that point, the subscriber unit can immediately attempt to open an audio channel, or can postpone attempting to open an audio-grade channel until a complete phone number has been dialed, or can postpone attempting to open an audio channel until the called party answers, since sometimes the party may not answer. In  
15 another variation, upon off-hook, a non-voice channel to the base station is obtained and then used to convey dial-tone status from the switch. Again, the subscriber unit can immediately attempt to open an audio channel, or can postpone attempting to open an audio-grade channel until either a complete phone number has been dialed, or until the called party answers.

In the preferred subscriber unit-detection embodiment, upon off-hook, the subscriber unit tries to establish an audio channel, and on failure, provides an audio signal (typically a tone or possibly even silence) to the user during which digit collection continues regardless of the type of tone. Thus, in one version, the audio signal is null (silence), but the subscriber unit continues processing digits, while in another version, the  
25 audio signal is a substantially dial-tone-like "fake dial tone", and in yet another version, the audio signal sounds different from dial-tone, for example a "fast busy."

In the preferred embodiment, once the call is determined to be an emergency call, it is tagged as emergency for the purpose of enhancing its reliability for the remainder of the call duration. A call so tagged will not be allowed to be dropped or otherwise  
30 degraded in response to other emergency call attempts.

In this embodiment, the subscriber unit decides whether or not the phone number is an emergency call. The subscriber unit unilaterally takes the decision to discontinue the call when it is determined that the call is a non-emergency call. In an alternate embodiment, the subscriber unit simply provides the emergency/non-emergency status of the call to the communication-station using one of the control channels normally used for status and channel assignment in the wireless communication system. The base station then uses this information, including the phone number (or partial number) that was dialed. This phone number is provided by the subscriber unit to the communication-station's channel allocation means which subsequently uses the phone number information to decide which calls may be dropped. In yet another alternate, if and when the subscriber unit can be sure the call is not an emergency call, the subscriber unit tells the communication-station immediately that the call is not an emergency. The communication-station can then perform a system capacity/load check to decide if the call should be allowed to continue. In such a case, the communication-station can temporarily store the emergency determination status to use when deciding which calls to drop (or degrade) if and when such dropping or degrading becomes necessary.

### *Base Station Detection of Emergency Numbers*

A WLL system is licensed to have a certain number of channels. One aspect of the emergency call communication channel allocation feature of the present invention allows a certain number of those full rate channels to be reserved (reserve channels) for detecting emergency calls. While this scheme reduces the maximum capacity of the system for non-emergency calls, the grade of service for emergency calls is dramatically improved.

Referring to **Fig. 3A**, the flow diagram for the base station detection of emergency telephone numbers is illustrated. In this alternate embodiment, all of the subscriber units of the present invention have priorities assigned to them based in part on the level of service reserved (*e.g.*, purchased) by the subscriber unit owner. When a channel request (for example for a call) is made, a priority flag **300** is sent to the base station. The base station determines if the system is at its maximum capacity **302**. If the

system is not at its maximum capacity, communication channels are available and the call is connected **304**.

If the system has reached its maximum capacity, the base station determines if the channel request being placed is for an outgoing call **306**, that is, whether the channel is request is not one for maintenance but for the purpose of placing a call beyond the base station. If the request being made is not for an outgoing call and the system capacity is at its maximum, the call is disconnected **308** and the user must try again later. If the request is for an outgoing call, the base station checks to see if the call is the lowest priority of all active calls on the system **310**. If there are lower priority calls on the system, calls of a lower priority are singled out to be disconnected **312**. Thereafter the lower priority call selected is disconnected **314** so that the higher priority call can be connected **316**.

If there are no lower priority calls on the system, the call is marked as an emergency call **318** and the base station performs further analysis on the call **320**. At this juncture the caller is provided with a full rate communication channel which is one of the several full rate communication channels of the system that are reserved for emergency call use.

Referring to **Fig. 3B** the analysis of a potential emergency call is further illustrated. This analysis is done one digit at a time. If the caller does not dial a digit within a time limit, *i.e.*, five (5) seconds **322**, then the system determines if all of the communication channels are in use, *i.e.*, if the telephone system has reached maximum capacity **324**. If the telephone system has not reached capacity, then the call is marked as a non-emergency call **326** and the system maintains the connection **328**. However, if the telephone system has reached maximum capacity **324**, then the caller is disconnected **330**.

If the caller does dial a digit within a time limit, *i.e.*, five (5) seconds **322**, then the system determines if the dialed digit matches the correspondingly positioned digit of any of a predefined sequence of numbers representing an emergency number **332**. The system then determines if all the digits dialed so far match any of a predefined sequence of numbers representing an emergency telephone number **334**. If dialed digits do not yet match a predefined sequence of numbers representing an emergency telephone number,



then the system determines if the caller is done dialing **336**. This is accomplished by known dialing rules, for example, if the first digit a caller dials is a one (1), then the caller must dial ten (10) more digits to complete the call. If the caller is not done dialing, then the system goes back to step **322** for the next digit. That is, the system checks if the caller has dialed another digit within a time limit, *i.e.*, five (5) seconds **322**, and so forth as described above. Otherwise, if the maximum number of digits has been dialed, and in step **334** a match to an emergency telephone number is found, then the system determines in step **338** if another caller must be disconnected in order for there to be maintained a full rate communication channel for another potential emergency call. If the system has reached maximum capacity **338**, then the system chooses a call to disconnect **342** and disconnects the caller **344** and maintains the connection for the emergency caller **340** and reserves a full rate channel for future emergency calls. In alternate embodiments that allow for multiple rate calls, such as half rate voice calls, or twice full rate data transfer calls, rather than disconnect a call, one or more calls are downgraded (for example from full rate 32 kbps to half rate 16 kbps, or from a 2-channel 64 kbps link used for data to a slower 32 kbps link) in order to provide the necessary free full-rate channel for the emergency call. If the system has not reached maximum capacity, then the system maintains the connection **340**.

#### **Communication Channel Allocation (Less Than Full Rate)**

A low rate communication channel is a communication channel which operates at a lower speed than a full rate communication channel. In one embodiment, the low rate communication channel operates at 250 bps which is 1/128 of a full rate communication channel. The full rate communication channels operate at 32 kbps. In order to use a low bit-rate communication channel, the telephone device uses compression using a special vocoder. The special vocoder is capable of working with two (2) discrete sine waves. The special vocoder is stored in a DSP located in either the telephone device or interface as described in the earlier embodiments. The two simultaneous tones are adequate to pass DTMF, dial tone, busy signal, fast busy, *etc.*, including all standard audio band signaling mechanisms used in telephone systems today. Thus when all of the full rate communication channels for a wireless local loop telephone system are in use, a caller can still receive dial-tone from the switch and dial a telephone number using a low rate

communication channel. Note that in this embodiment, the audio signal compressor in the subscriber unit does not explicitly "recognize" the digits. It only finds discontinuities of tones and signals the frequency and amplitude of the tonal components as they appear. It is up to the base-station to turn this tone sequence encoding into digit sequences and then, perhaps, do emergency call discrimination.

Many methods are known for providing low-rate channels in a manner compatible with a given air interface standard. The preferred embodiment uses the Personal HandyPhone system (PHS) standard described, for example in the Association of Radio Industries and Businesses (ARIB, Japan) Preliminary Standard, Version 2, RCR STD-28 and Technical Standards of the PHS Memorandum of Understanding Group (PHS MoU -- see <http://www.phsmou.or.jp>). In time-division (*i.e.*, slotted) air-interface standards such as PHS, 1/2-rate (16 kbps) and 1/4-rate (8 kbps) connections are supported by providing rate handshaking between the subscriber unit and the base station at the start of the low-rate connection, and then transmitting only on every other (for 1/2-rate) or every fourth (for 1/4-rate) communication slot that would normally be used by a full-rate connection. While not directly supported in the PHS standard, this method may be extended in an obvious manner to support any fractional rate, such as the preferred rate of 1/256. Similar fractional-rate methods may be applied to other air-interface standards. Alternatively, low-rate connections may be carried out using any of a variety of well-known random access technique. The random access uplink technique used in PHS for link channel requests can be easily modified to carry low-rate compressed audio traffic on a different dedicated channel. With this method, uplink messages are sent on a shared random access channel and the base station positively acknowledges each message it receives. If a subscriber unit does not receive an acknowledgement, it waits a proscribed amount of time and retransmits. In this way many low-rate uplink users may share a common channel. On the downlink, the base station sends messages (e.g., compressed audio signals) on a common downlink channel, using a messaging protocol analogous to that used for the downlink PHS downlink link channel assignment messages. Each message contains both a payload and a subscriber unit address field. The address field enables the targeted subscriber to identify and extract those messages it is intended to receive.

How one may achieve compression for use in the low-rate channel is now described in more detail. Many methods for reducing downlink bandwidth may be used. For example, if the switch is able to generate only a small number of distinct audio signals during call connection, e.g., dial tone or fast busy, then these audio signals may be broadcast to all subscriber units using a single broadcast channel, switching between the audio signals in a cyclic fashion. A very low-rate downlink signaling channel is then used to individually instruct a subscriber unit to either play back a particular received broadcast audio signal to the telephone device, to play back silence to the telephone device, or to enter normal audio processing mode. Alternate compression schemes may be used to pass the signaling information. Methods for compressing audio signals are known in the art. Compression methods take as input a sampled digital version of an audio signal and produce a digital sequence that represents the salient audio features of the signal in compact form. Compressing audio signals that consist of a mixture of tones is a particularly straightforward problem; compression methods that work well for speech signals will also work well for mixtures of tones, such as occurs in DTMF signals, as mixtures of tones may be viewed as a special case of audio signals, and indeed many compression methods used for telephony applications are designed specifically to pass DTMF tones and other signaling tones with minimal distortion. Any standard low-rate speech compression method may therefore be used in the invention, provided that the method preserves the frequency of signaling tones.

Preferably, however, a method with much lower computational complexity is used. Many methods exist for counting the number and determining the frequency of tones in a signal that consists of a mixture of tones. The preferred method divides the quantized audio sequence into blocks of duration 10 millisecond, applies a computationally efficient tone estimation method such as ESPRIT (see, for example, United States Patent 4,965,732 to Roy, III, *et al.*, entitled METHODS AND ARRANGEMENTS FOR SIGNAL RECEPTION AND PARAMETER ESTIMATION), and outputs a sequence of values for each 10 millisecond block representing the number, frequency, and intensity of those tones (up to a maximum of two tones) whose intensity exceeds a proscribed minimum sensitivity value for DTMF detection. If no significant tones are present then a silence indicator is produced for the block. The compressed

sequence that results from the processing of the 10 millisecond blocks is then subject to run-length coding to further collapse tones sustained over multiple 10 millisecond blocks into a single frequency/intensity/duration indicator. Other compression methods more efficient than run-length coding may also be used.

5 An alternate embodiment of the present invention which uses a low rate link to the base station where detection of the emergency number sequence is made is illustrated in **Fig. 4A** and **Fig. 4B**. The subscriber unit goes off-hook **400**. The subscriber unit requests a communication channel **402**. At this point, a dial tone is not present. The base station determines if there is an open full rate communication channel which can be  
10 assigned to the caller **404**. If an open full rate communication channel is available, the open full rate communication channel is assigned to the caller **406**. The system then provides a dial tone to the caller **408**. The call proceeds as a normal call **410**.

If there are no open full rate communication channels available, then the subscriber unit is provided with a low bit-rate communication channel **412**. A low bit-  
15 rate communication channel is a communication channel which operates at a lower bit-rate than a full rate communication channel. In one embodiment, the low rate communication channel operates at 250 bps which is 1/128 of a full rate communication channel. The full rate communication channels operate at 32 kbps. In order to use a low rate communication channel, the telephone device uses compression using a special  
20 vocoder. The special vocoder is capable of working with two (2) discrete sine waves. The special vocoder is stored in a DSP located in either the telephone device or interface as described in the earlier embodiments. Such a compression allows DTMF tones and possibly one or more signals to be transmitted to the base station. Such a low rate vocoder is also capable of transmitting the dial tone, busy signal, and other call progress  
25 signals to the subscriber unit in the downlink direction.

The base station provides a dial tone to the caller and a DSP at the base station (base station DSP) listens for the codes for DTMF tones **414** which have been passed from the subscriber unit to the base station on the low bit-rate channel. Referring now to **Fig. 4B**, **422**, if the caller does not dial a digit within a time limit, *i.e.*, five (5) seconds  
30 **422**, then the system determines if all of the communication channels are in use, *i.e.*, if

the telephone system has reached maximum capacity **424**. If the wireless system has not reached capacity, then the call is marked as a non-emergency call **426** and the system assigns a full rate channel and dials the digits dialed so far, and the call is continued as a normal call **428**. However, if the telephone system has reached maximum capacity **424**,  
 5 then the caller is disconnected **430**.

If the caller does dial a digit within a time limit, *i.e.*, five (5) seconds **422**, then the base station determines if the dialed digit matches the correspondingly positioned digit of any of a predefined sequence of numbers representing an emergency number **432**. The system at the base station then determines if all the digits dialed so far match any of  
 10 a predefined sequence of numbers representing an emergency telephone number **434**. If dialed digits do not yet match a predefined sequence of numbers representing an emergency telephone number, then the system determines if the caller is done dialing **436**. This is accomplished by known dialing rules, for example, if the first digit a caller dials is a one (1), then the caller must dial ten (10) more digits to complete the call. If the  
 15 caller is not done dialing, then the system goes back to step **422** for the next digit. That is, the system checks if the caller has dialed another digit within a time limit, *i.e.*, five (5) seconds **422**, and so forth as described above. Otherwise, if the maximum number of digits has been dialed, and in step **434** a match to an emergency telephone number is found, then the system determines in step **438** if another caller must be disconnected in  
 20 order for there to be maintained a full rate communication channel for another potential emergency call. If the system has reached maximum capacity **438**, then the system chooses a call to disconnect **442** and disconnects the caller **444** (or chooses one or more calls to downgrade and so downgrades these calls) and assigns the new full-rate channel for the emergency caller **440**, including dialing the number dialed. Similarly, if the  
 25 system has not reached maximum capacity, then the system assigns a new full-rate channel for the emergency caller **440**, including dialing the number dialed.

In alternate embodiments that allow for multiple rate calls, such as half rate voice calls, or twice full rate data transfer calls, rather than disconnect a call, one or more calls are downgraded (for example from full rate 32 kbps to half rate 16 kbps, or from a 2-  
 30 channel 64 kbps link used for data to a slower 32 kbps link) in order to provide the necessary free full-rate channel for the emergency call.

## *Call Disconnect Procedure*

The WLL system of the preferred embodiment of the present invention provides six levels of caller priority which can be assigned to different customer classes. High priority outgoing calls have an improved chance of connecting in a system that has reached maximum call capacity. The priority level of each subscriber unit is assigned by the base station when the subscriber unit is brought on line. When the system is operating at maximum capacity and a call is attempted, the priority of the new call's subscriber unit is compared to the priority of existing calls on the system. A new call may preempt any call that has a lower priority level than itself. A lower priority call is be disconnected so the new call can be assigned its resources. If the call is from a multi-rate subscriber unit, one or more than one call resource is be disconnected so that the multi-rate call can be accommodated at the higher rate. For example, double-rate calls use two channels and are supported. Similarly, half rate calls use half a channel. The method of selecting which call(s) to disconnect is performed as follows:

1. The set of possible calls to disconnect is restricted to those with the lowest priority that are connected to the system, excluding those calls that are designated as emergency calls.
2. If there are any calls among those lowest priority calls which are in the process of being connected, a call is selected from among them, and that call is not connected.
3. If there are no calls being connected (*i.e.*, all calls are already connected), a call is selected at random from the set of lowest priority calls and disconnected in favor of the emergency call.
4. If there are no calls with a lower priority on the system, the call will go through a process to determine if it is an emergency call.

In short, any user of a WLL system who dials a recognizable emergency call using either a DTMF or pulse telephone will have an increased chance of the emergency call going through, even if the system is operating at its maximum capacity.

In alternate embodiments that allow for multiple rate calls, such as half rate voice calls, or twice full rate data transfer calls, rather than disconnect a call, one or more calls

are downgraded (for example from full rate 32 kbps to half rate 16 kbps, or from a 2-channel 64 kbps link used for data to a slower 32 kbps link) in order to provide the necessary free full-rate channel.

### **Time-Out Procedure**

5           In order for the system of the present invention to not be overcrowded with repeated erroneous calls, a time out program is resident in the DSP of the base station. This program allows a user selectable certain number of non-emergency calls to be attempted during times of peak use from a given subscriber unit. When a subscriber unit exceeds the number of allotted call attempts during a peak period, the base station denies  
10 further access to that subscriber unit for a set period of time. After the expiration of that time, the subscriber unit is again permitted to attempt phone calls. In this manner, the system is kept from being overcrowded in the processing of those calls that are potentially emergency in nature.

### **Base Station-Based Discrimination: Some Variations**

15           The preferred embodiment for base-station based phone number analysis for the purpose of emergency/non-emergency call discrimination also includes base-station dialed digit detection. As described above, in one version, low-rate channels are used during the call setup phase to carry the dial tone, DTMF digits, pulse-dial-events, and other low-information-bit-rate call setup signaling. In another version, a certain number  
20 of full-rate reserve channel is made available. Calls in their startup phase can occupy a full-rate reserved channel. When a non-emergency call is confirmed in the reserved channel, the call is moved into the non-reserved channel set. If this cannot be accomplished, the call is discontinued.

          In the low-rate channel scheme, in one version, the low-rate channel is preserved  
25 until connect. When it is confirmed that the wireless system is at full load and the non-emergency status is confirmed, the call is discontinued. When, on the other hand, the wireless system is not at full capacity, the call is promoted to a full rate (*i.e.*, voice-capable) channel if and when the call connects. When it is confirmed that the wireless system is at full voice channel capacity and that the call is an emergency call, another call  
30 is dropped (or one or more calls are degraded in data-rate) to make room for the

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emergency call. Preferably, in such a case, the emergency status is remembered by the base-station for use in call dropping decisions.

In the low-rate channel scheme, in another version, the low-rate channel is used only until emergency status can be confirmed or denied. When it is confirmed that the wireless system is at full load and the non-emergency status is confirmed, the call is discontinued. When, on the other hand, the wireless system is not at full capacity, the call is promoted to a full rate (*i.e.*, voice-capable) channel if and when the call connects. When it is confirmed that the wireless system is at full voice channel capacity and that the call is an emergency call, another call is dropped (or one or more calls are degraded in data-rate) to make room for the emergency call. Preferably, in such a case, the emergency status is remembered by the base-station for use in call dropping decisions.

In the reserve full-rate channel scheme, in one version, when a call made on one of the reserved channels is confirmed to be an emergency call, a non-emergency call is dropped to restore a channel to the reserved channel pool. In the preferred version, calls that have not (yet) been confirmed as emergency calls that are occupying one of the reserved channels, have a inter-digit dialing time imposed to limit time occupying a reserved channel. In yet another version, any call that has not (yet) been confirmed as an emergency call, and that is occupying a reserved channel, has a maximum total dialing time imposed to limit the time any call can occupying a reserved channel.

## 20 **General System Requirements**

The system of the present invention is a TDMA system that operates under the personal Handiphone Standard (PHS) and includes a plurality of subscriber units. Generally each subscriber unit has three Motorola ® M56303 digital signal processors (DSP), whose characteristics are incorporated herein by reference in their entirety, one for transmission, one for reception, and one for audio signal coding and decoding. These DSPs are not meant as a limitation. Other DSPs having the capabilities of these specific DSPs are considered within the scope of the invention. Further, it is anticipated that future DSPs will be available having similar or more powerful characteristics, and would find use in the present invention. Further, it is anticipated that many of the functions now implemented by DSP programs may in the future be incorporated into special purpose



hardware, for example as part of an application specific integrated circuit (ASIC) or part of a very large scale integrated circuit (VLSI). As would be clear to those of ordinary skill in the art, a general purpose microprocessor may also be used instead of a DSP device.

5           The base station comprises several Motorola ® M56303 DSPs, whose characteristics are incorporated herein by reference in its entirety. The number of DSPs depends on the number of antennas in the antenna array and the number of network connections available for the base station. In general, there is one for each time slot on the receive side and one for eight slots on the transmit side (the PHS system has four  
10 receive and four transmit time slots in each frequency band), although this DSP is not meant as a limitation. Several PowerPC microprocessors (Motorola®/IBM®) control the DSPs. The Motorola ® DSP56303 is a 24-bit processor of the family of processors of the designation DSP56300. Other processors of this family would be suitable substitutes as would other DSPs or DSP ASIC cores from other manufacturers, or microprocessors, or  
15 special purpose hardware or other processing means as would be clear to those in the art.

Although the present invention has been described in detail for purpose of illustration, it is understood that such detail is solely for that purpose, and variations can be made therein by those skilled in the art without departing from the scope of the invention as described. The present invention is defined by the following claims: